CEMENT AND LIME MANUFACTURE

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Feeders and Feed Gears for Crushing and Grinding Mills.

FEED gears and feeders have an important influence upon the behaviour and product of crushers and grinding mills, as any variation in the amount or size characteristic of the feed or in its density will influence the product. The size will be more uniform if the mill is fitted with sieves and is used for preliminary duty, because the sieves will determine the upper dimension of the particles leaving the mill; it is, however, not possible to alter the hardness, toughness or grindability of the material.

The feeder installed with the small Continental ball mills when they were originally introduced into this country was of the shaker-trough type. The trough was suspended upon four hanging links, and the end under the feed hopper was rather higher than the end situated over the mill inlet. The feed was run-of-crusher material up to 1 in. to 1¼ in. cube. The trough was moved by a double cam operating at a speed of possibly, 100 revolutions per minute, which pressed the trough forward against the resistance of a heavy spring which caused a quick return. A movement of up to ¾ in. was provided for, but it could be reduced to any desired dimension by means of an adjustable buffer stop; this stop could be easily adjusted while the machine was at work. The feed could be cut off entirely by stopping the cam. This feeder, though noisy, was quite satisfactory, possibly due more to the type of mill than to the feeder.

The mill was of the drum type, fitted with sieves which determined the maximum size of the product—except for any leakage that took place; the amount of leakage was, however, small apart from the nibs that got through when a break-away occurred with the sieves or sieve plates. The mill was of large diameter but short in length, and the vibration noise when it was fully charged with grit was quite different from the sound when it was not fully charged; the principal duty of the

operator was to adjust the feed so that the correct vibration sound was maintained and in this way the mill was kept uniformly charged.

It is possible that the output quantity of the mill varied considerably over short periods, but the largest particle size in the product was consistent. The quantity variation might have been due to a variation in the size of the feed or to a change in grindability, but every variation could be compensated for in the feed adjustment and all possible changing conditions could be satisfied.

The shaker-trough feeder was not considered suitable for mills of the compound type and of much larger capacity owing to the absence of the " sound characteristic " (the " electric ear " was not available at that time) and owing also, possibly more so, to the many variables.

The rotating table has become almost a standard form of feeder and is nearly always supplied with new mills. Two tables of this type, but of different diameters and rotating at different speeds, are usually arranged side by side for clinker and gypsum respectively, but owing to the varying conditions the performance of table feeders leaves much to be desired. The quantity of feed delivered varies with the height of the material in the hopper, more feed being delivered when the hopper is full than when it is empty. The quantity of feed will also vary with the size classification of the material ; if the material is clinker produced by the rotary kiln, when it is small and " marbly " it will tend to spread on the table and an excess quantity will be delivered. Changes in the density, hardness, or toughness of the clinker, owing to changing conditions within the kiln, also call for a change in the quantity of feed, and such changes cannot be made with precision with the table feeder. It is easily possible, without any adjustment, for the weight of feed delivered over short periods by this type of feeder to be up to 7½ per cent. greater or less than the mean quantity delivered over a long period. Moreover, with large-capacity mills, the effect of an adjustment of the feeder cannot be verified in the product for twenty or thirty minutes after the adjustment is made ; further, it takes some time for the new conditions to become stabilised, and if the adjustment made is not correct the whole process has to be gone through again.

From information available it appears possible that a difference of, say, 5 per cent. above and below the mean figure would be sufficient to cover short-period variations in the grindability of the clinker when produced by the same kiln, and from the same raw material, and ground to the same residue in the finished product. If, therefore, a satisfactory type of constant-weight feeder or constant-volume feeder can be devised, it will still require supplementary adjustment to be operated at will to suit the characteristic of the cement being dealt with. This adjustment could be left to the judgment of the operator and would be determined by observation of the clinker being fed to the mill. Training and experience would be necessary, but the idea appears promising and is worth a trial—some adjustment is sure to be found necessary. If more than one residue in the finished product is likely to be required the arrangement could be amplified to provide for the 5 per cent. margin above and below the required figure. It should be pointed out, however, that the classification of the media within the mill will depart from its best efficiency if too great a change is made in the final residue of the product.

Several types of elementary feeder will now be described with a note of their best duty and performance, followed by a description of an approved constant-weight feeder and an approved constant-volume feeder, respectively.

Figs. 1 and 2 indicate diagrammatically simple forms of roller feeder and belt-conveyor feeder, either of which would be suitable under the vertical discharge openings indicated. The surface of the roller should be rough; the centre line of the roller may be slightly towards the discharge side of the hopper mouth; the

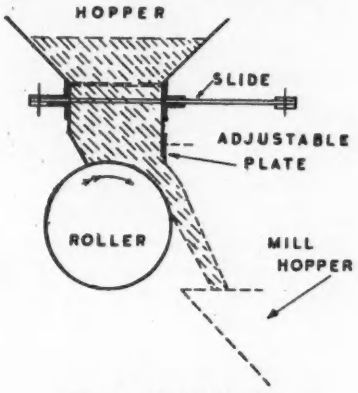

Fig. 1.—Roller Feeder.

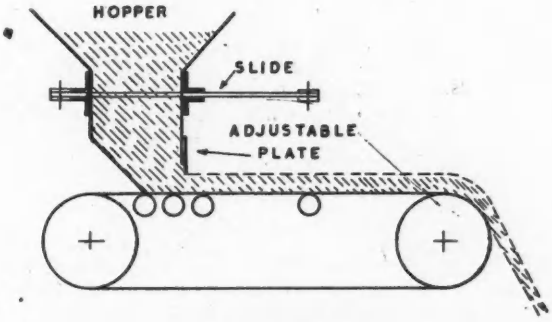

Fig. 2.—Belt Feeder.

roller, shaft, and bearings should be strong enough to support the full head of material in the hopper; a slide is indicated at the discharge so that the best or most satisfactory form of opening is obtainable; an amount of speed regulation of the roller would possibly prove an advantage. A roller feeder would be satisfactory for dealing with semi-crushed stone where quantity or precision of feed is not required.

The belt shown in Fig. 2 should be carried across the opening; the part of the belt that is under the opening, and just beyond, should be well supported by rollers; the belt may be of any desired length, which may prove an advantage

under some conditions; an amount of speed regulation would be a distinct advantage.

Both these feeders would be suitable for a crusher dealing with oversize material, or for feeding a conveyor or an elevator, but neither is likely to be satisfactory for feeding a mill or similar machine owing to the absence of definite quantity control.

Figs. 3 and 4 indicate a reciprocating cradle feeder and a reciprocating tray

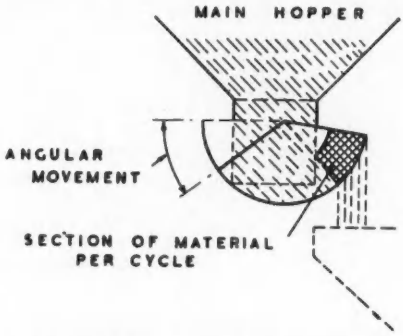

Fig. 3.—Reciprocating Cradle Feeder.

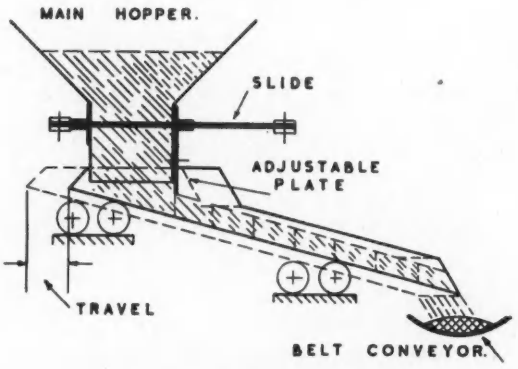

Fig. 4.—Reciprocating Chute Feeder.

or chute feeder respectively. Both are operated from a crank disc having an adjustable radius; each is suitable for dealing with crushed or cubical material containing a normal percentage of smalls; wear would probably be greater with the unit shown in Fig. 4 owing to the greater amount of sliding that will take place. The chute feeder has a definite advantage in that its point of delivery can be remote from the hopper outlet, whereas the cradle feeder must be relatively beneath the hopper. Both feeders are suitable for material of, say, from 2 in. down with a percentage of smalls. They also promise good performance where

accuracy of quantity is not of importance, but neither is likely to be suitable for feeding a mill if accurate control of quantity is desired.

Figs. 5 and 6 indicate a screw-conveyor feeder and a star feeder respectively. Both are suitable for dealing with fine or dusty material and are frequently used for cement or cement grit and coal. They can each be used as volumetric feeders provided that arrangements are made to exclude excess air at the time of measurement. If the material is quite dry, full volumes can be assured by the use of a

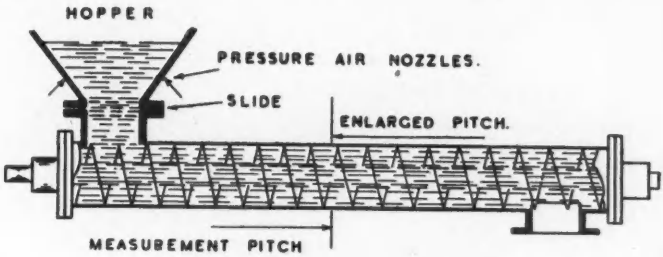

Fig. 5.—Spiral Conveyor Feeder.

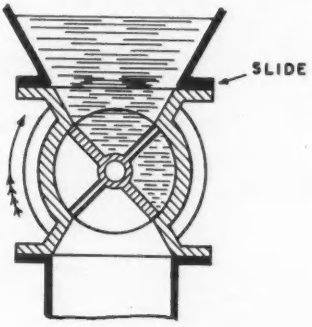

Fig. 6.—Star Feeder.

little pressure air (dry) at the base of the primary hopper close to the point of attachment of the feeder. The barrel of the screw-conveyor feeder should be relatively long to reduce the effect of flushing— if flushing takes place or is likely to do so. The amount of pressure air used should be as small as possible, just enough to result in flow of the material. Star feeders are generally used in the feed service of air-swept coal mills, and other mills where the unground coal is small and substantially dry. Under normal conditions both these feeders call for frequent hand adjustment of the rate of feed and this form of adjustment is most suitable for kiln duty.

It is understood that volumetric feeders of the cubimeter type have been tried on clinker, but it became necessary to remove them for reasons that have not been

stated. In a general way the cubimeter deals with a relatively thin layer of material. If the material were slightly damp coal it would bed quietly on the belt, and little spread would take place ; if the material were of a dry pebbly nature, similar to clinker, and if the layer were thin, there would be a decided tendency to scatter or spread and the figure for volume would be unreliable.

Mass feed of this type should be preferably of approximately rectangular form with the sides contracted, and the length of the conveyor, say, ten or twelve times the depth of the section. Only a small difference in cost is likely to be involved, but the additional length might easily result in the difference between success and failure ; in any case, it would ensure the mass retaining its form for a good distance from the cubing point before the risk of spread or scatter obtained.

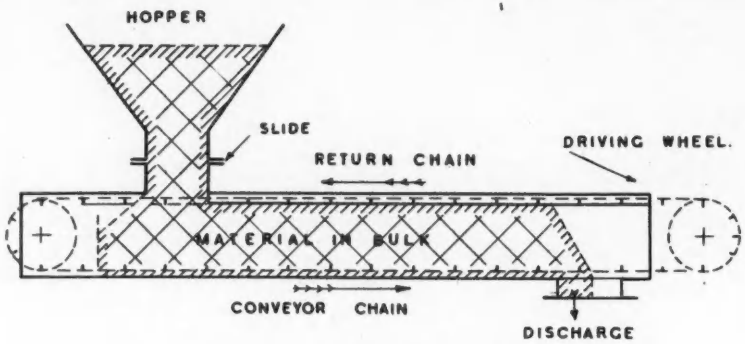

Fig. 7.—Redler Conveyor Feeder.

Limited experience with the " Redler " conveyor suggests that this type might be successfully applied as a volumetric feeder for clinker ; the casing would be consistently full, its length would prevent premature spread, and the quantity of material delivered would be determined by the speed at which the chain travelled. The casing would be open at the top near the discharge end, and enable the clinker to be observed at all times, and speed adjustment could be made as necessary. The feeder would be driven by its own motor, and the controller for speed regulation arranged in small increments, the steps being of approximately equal value for the operator's convenience. A typical arrangement of a Redler equipment for this duty is indicated in Fig. 7 ; as soon as the feeder has settled down to the capacity of the mill the only adjustment necessary would be that to allow for the difference in density or grindability of the material. Redler conveyors are being adopted for many purposes and for many kinds of material, and varied forms of link have been evolved to obtain satisfactory results with materials of widely different characteristics.

Figs. 8 and 9 indicate a form of constant-weight feeder. The fixed end of the belt is placed under the main hopper so that a difference in the level of the clinker in the hopper will have little effect upon the weigher. The lever framework

carrying the conveyor and the driving motor is of balanced construction ; it is supported upon a pair of trunnion pins which act as the fulcrum of the complete system, and the whole is mounted upon and attached to a form of hopper mouth-

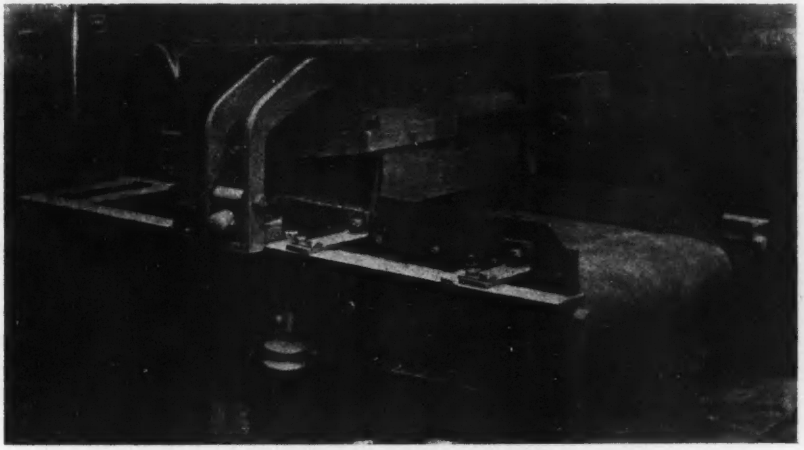

Fig. 8.—Constant Weight Feeder.

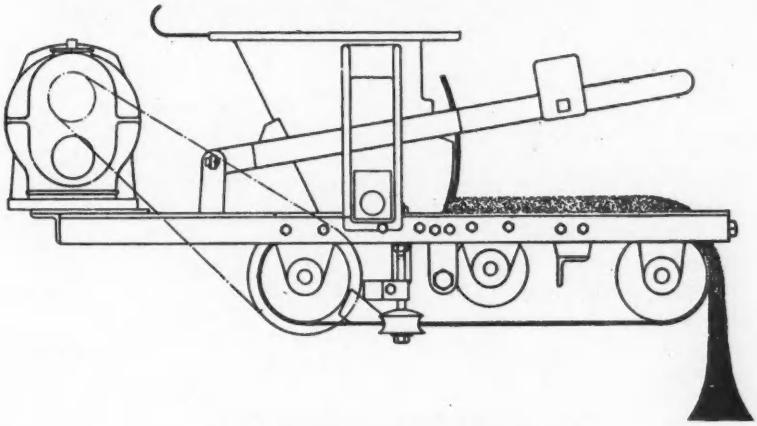

Fig. 9.—Constant Weight Feeder.

piece prepared for fixing to the bottom of the main feed hopper. The opening from the hopper mouth slopes in the direction of travel of the belt. The feed opening is covered with a curved slide, attached to and controlled by a lever, which in turn is connected by a link to the main levers. The movement of the curved slide is such that when the discharge end of the belt is lightly loaded and tends to rise,

the slide rises also and allows more feed to pass ; this increases the load on the belt and causes depression which in turn tends to close the slide, and this process is automatic. Frequency of movement is, or may be, an advantage, but if systematic oscillation takes place, it may be necessary to apply a dashpot to act as a restraining element.

Two methods of weight control appear possible : (1) Varying the speed of the belt but keeping on it a constant depth of material, and (2) Varying the depth of material but keeping the speed constant. Theoretically, either of these methods should result in a substantially constant weight of feed being delivered.

With regard to (1), the variable-speed motor should enable the belt speed to be varied at will and with precision. This variation should provide for up to, say, 7 per cent. above and below the usual weight of feed dealt with and should be obtainable in small increments ; its use should be left to the discretion of the operator and used to allow for the difference in the apparent characteristics of the clinker. With regard to (2), changing the depth of material on the belt could be effected by the use of detachable weights applied to the motor end of the main levers, adding weights to obtain more feed and removing them to obtain less feed. Applying weights would cause the discharge end of the belt to rise, and this would enlarge the opening and enable more feed to be delivered, and *vice versa*. Applying weights in this way might set up a condition of instability of balance and cause oscillation, but this would possibly soon right itself ; in the event of it not doing so it would be necessary to apply a small dashpot. Assuming consistant operation of the feeder, a constant weight of material would be delivered to the mill and small adjustments would be necessary only to allow for the difference in the observed characteristics of the material ; this adjustment would be left to the operator.

Theoretically, a feeder of either the constant-volume or constant-weight type should provide a reasonably constant rate of feed, but the constancy of either kind will be, or must be, disturbed to compensate as far as practicable for the difference in the characteristics of the clinker. It must not be overlooked that the effect of any adjustment of the quantity of feed cannot be verified at the discharge end of the mill for some twenty or thirty minutes after the adjustment has been made.

The demand for a consistent residue in the finished product is insistent, and anything that helps to meet this demand should be adopted and amplified in every way possible. A regular feed for the mill is possibly one of the most important ways of obtaining uniformity.

Joining Two Kilns.

IN order to effect an economy in fuel consumption and to improve the quality of the clinker, a factory of the Lawrence Portland Cement Company, at Maine, U.S.A., has been reconstructed. The work includes the joining together of parts of two kilns 200 ft. long and using them as one unit 356 ft. long.

When it was built in 1927 the plant had two 11-ft. by 200-ft. kilns, fired with pulverised coal from a bin system, and clinker discharged into 10-ft. by 90-ft. rotary coolers. The coal mill, housing a dryer and two pulverisers, scales, and feeders, was attached to the east end of the kiln building and in line with the kilns. In 1940 direct-firing was substituted for the bin system, using two bowl mills and eliminating the old dryer and pulverisers. The plant will continue to operate by the wet process with two compeb mills for raw grinding and with disc filters to reduce the moisture content of the slurry from 37 to 18 per cent.

Before making this change, various possibilities were studied in the use of existing equipment. It was finally decided to join sections of the two 11-ft. by 200-ft. kilns to make one kiln 11 ft. by 356 ft. long, with a modified chain system, and to replace the rotary coolers with an inclined movable-grate cooler. The bowl mills will continue in use for direct-firing, but as one of these mills would, under normal conditions, supply enough fuel for the single kiln the other will act as a standby. The extended kiln is believed to be the longest kiln in the world fed with filter cake, and the great length coupled with the use of an elaborate system of heat recuperating chain loops suspended in the feed end of the kiln, are the principal reasons for the expected coal saving. Also, much lower stack gas temperature will be obtained. By lengthening the kiln the time of reaction for the raw material to change into clinker is increased, which results in improved quality. The use of the inclined-grate cooler will provide quick cooling or " air-quenching " of the clinker, which also is considered an advantage from the standpoint of quality. The new kiln uses the existing stack. Each of the old kilns was supported on four tyres spaced at approximately 52 ft. centres. By erecting three new kiln piers it was possible to support the extended kiln on seven tyres without changing their position with respect to the shell.

Difficulties were encountered with the sub-foundations for the new kiln piers. It was found that for pier No. 1, for instance, solid rock was about 43 ft. below ground level, which was about 20 ft. deeper than for the present kiln piers. This required piled supports for all three new kiln piers.

Each of the kilns, with firebrick lining, weighed about 400 tons. After the three new piers were built, wooden trestles, supported on the floor, were placed at intervals throughout the length of the kiln building. Two heavy H-beam stringers were placed on top of the wooden trestles parallel to the kiln axis. No. 1 kiln was supported on eight wooden cradles and heavy steel skids rolling on heavy pipe rollers in turn supported on the H-beam stringers. Kiln No. 1 was then

moved down hill on the pipe rollers a distance of 156 ft. to its final position. The section of No. 2 kiln to be used was then rolled on its tyres on to the piers to line up with No. 1 kiln and the two sections were then riveted together.

No changes have been made in the raw feed to the kiln except to install a belt conveyor to combine the discharge of both filters into a single feeder. Each filter had a reserve capacity for one kiln but neither had enough to feed the new kiln. It was therefore necessary to leave the Ferris wheel feeders and filters intact as originally installed and to synchronise the Ferris wheels and to operate them from a common source on the new kiln drive. The capacity of the two kilns as originally installed was 16,700 tons of clinker per month. It is anticipated that the new kiln will produce 12,500 tons per month with a reduction in coal consumption of about 150 lb. per ton.

The Cement Industry in Mexico.

DURING the war there has been a considerable increase in the production of Portland cement in Mexico. In the year 1942 there were eight factories with an annual capacity of 559,550 metric tons; with the new factories and the enlargements of existing factories since carried out and now in progress, by the end of the year 1945 the capacity will be 1,445,000 metric tons a year. The total electric power required will be 29,750 h.p., of which 18,260 h.p. will be taken from the public supply and the remainder generated at the works; of the power generated at the works, 2,820 h.p. will be generated by Diesel plants, 640 h.p. by hydraulic plant, and 8,030 h.p. by steam plant. Figs. 1 to 4 (see pages 71 and 72) show some of the more recent Mexican installations.

In Fig. 1 is shown the new kiln at the Tolteca works, which previously comprised a 285-ft. by 8-ft. and a 90-ft. by 9-ft. kiln. The new kiln, by Allis-Chalmers, is 300 ft. long by 9 ft. 5 in. in diameter, enlarged to 11 ft. diameter in the clinker zone. The total production capacity of the plant is now 750 tons a day. A Babcock & Wilcox ball mill and a Sturtevant air separator have also been recently installed at this works.

Fig. 2 is a view of the Guadalajara cement factory, which was put into operation in May, 1944. Beneath the kiln are the clinker cooler and dust chamber.

The works at Cruz Azul, which started production in November, 1944, is shown in Fig. 3. The covered storage yard is served by a crane for handling raw materials and cement clinker. The water tanks seen on the right of the photograph are for cooling the water used in the power house, which has a capacity of 1,375 kW. The raw materials used are limestone rock and shale.

Fig. 4 is a view of the kiln at the new Monterrey works. It is 175 ft. long by 10 ft. diameter, and has a capacity of 270 tons a day.

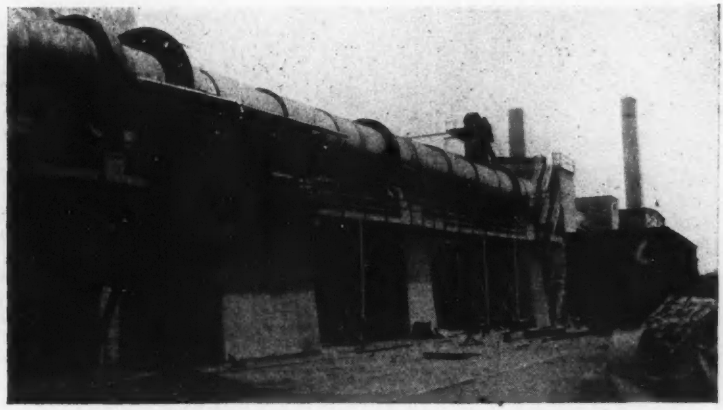

Fig. 1.—285-ft Kiln at Tolteca Works, Mexico.

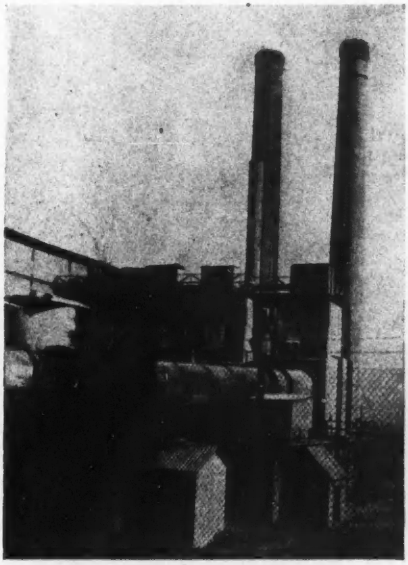

Fig. 2.—The Guadalajara Cement Works, Mexico.

THE CEMENT INDUSTRY IN MEXICO.

(See page 70.)

Fig. 3.—Cement Works at Cruz Azul, Mexico.

Fig. 4.—175-ft Kiln at Monterrey Works, Mexico.
(See page 70.)

Refractories in Portland Cement Manufacture.

By LEOPOLD TSCHIRKY.

[IN this article the author (of the General Refractories Company of Philadelphia) discusses the latest developments in the use of refractory materials by the cement industry in the United States.]

The improvements and changes in the properties of the finished refractories now being furnished to the Portland cement industry are not, generally speaking, the result of novelties in raw material supplies. The fireclays from Pennsylvania, Kentucky, Ohio, Missouri, and Texas remain the chief materials for fireclay bricks. The diaspore clays from Missouri and kaolin from Georgia continue as the chief sources of the high-alumina and special refractories made from these materials. The Washington magnesite, supplemented by the excellent magnesites made from sea water, remain the chief source of basic material. The chrome ores from Cuba are essentially the same type that have been imported for years. Therefore, the improved refractories of to-day are rather the result of a better understanding of their properties and the reduction to practice of methods of developing and controlling them.

A better understanding of the possibilities of refractories of the aluminium-silicate type, which includes most of those heretofore supplied to the Portland cement industry, has been gained from the use of such phase-rule diagrams as those of the system Al_2O_3—SiO_2 (*Fig.* 1) and CaO—Al_2O_3—SiO_2 (*Fig.* 2). Likewise the possibilities in basic refractories, which have gained wide favour for burning zone problems too severe for refractories in the aluminium-silicate classification, is gained from the use of phase-rule diagrams for combinations including magnesia (MgO), as the one for the system CaO—MgO—SiO_2 (*Fig.* 3). The question of making suitable brick from fireclays, in the light of these phase-rule diagrams, is the problem of converting an almost amorphous raw material into a stable mass of maximum crystallinity. With an understanding of these phenomena we have learned that if we submit raw clays to a series of time-temperature tests, we can anticipate rather exactly the volume stability of the brick we can make from the clays as well as the subsequent stability of the brick in service. The development of knowledge of properties dependent mostly on composition has been followed by scrutiny of the mechanics of certain physical properties, which result largely from processing and are factors in the subsequent life of refractories.

If we except slagging, the most common type of failure of refractories in the cement industry is spalling. For many years we proceeded on a theory, unsupported by physical studies, that all spalling was due to thermal shock resulting from temperature fluctuations. Later it was realised that spalling was a much more complex phenomenon and was related not only to thermal shock but also to structural or textural changes in the brick. Further studies emphasised the importance of certain definite measurable properties of refractories related to spalling. These properties in turn are affected by practically all the various operations in manufacturing a refractory. The extent to which grain size, mix,

moulding pressure, and burn affect spalling has engaged the attention of the refractories manufacturers.

In general, the conventional manufacture of refractories has been effected in five unit operations: (1) Grinding and screening; (2) mixing; (3) pressing or moulding; (4) drying, and (5) burning. The recognition of high bulk density in any given group of refractory materials as the most important single property which may be controlled in manufacture, and which affects the greatest number of other important properties in service, such as strength, volume stability, spalling resistance, and conductivity, has resulted in the application of most of the more recent and novel principle in manufacturing.

The first approach to increased density is the size of the grains constituting more recent and novel principles in manufacturing.

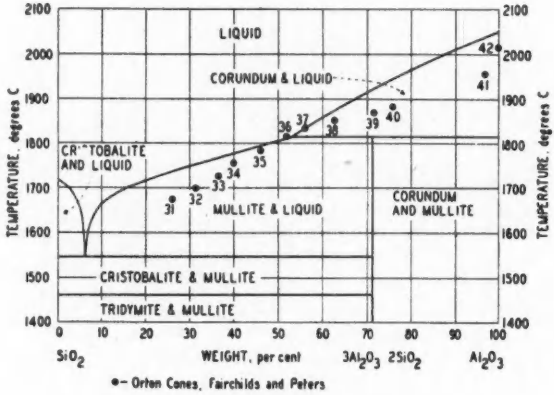

Fig. 1.—Phase-rule Diagram of the System Al_2O_3-SiO_2.

screening out grains falling within certain sizes and recombining them in definite proportions. The application of this principle is, of course, modified by a number of factors. It may be used most successfully on hard and highly crystalline materials which do not compact readily under pressure and, conversely, is of least value in mixes of inherently high plasticity.

The true function of the mixing operation is the distribution of the plastic or bonding materials so as to coat thoroughly the non-plastic constituents; in other words, to provide a lubricant during the subsequent moulding operation to create free plastic flow of the batch particles and permit them to be bonded into a mass with the minimum of voids. Improvements in mixing have been made which permit a more effective coating of plastic material on the non-plastic grains, a reduction in the percentage of plastic material required to secure a good bond, and, not least important, to be able to do this without crushing the grains during mixing.

An obvious method of increasing density, attended by many practical difficulties, is to increase the moulding pressure. This did not follow until one

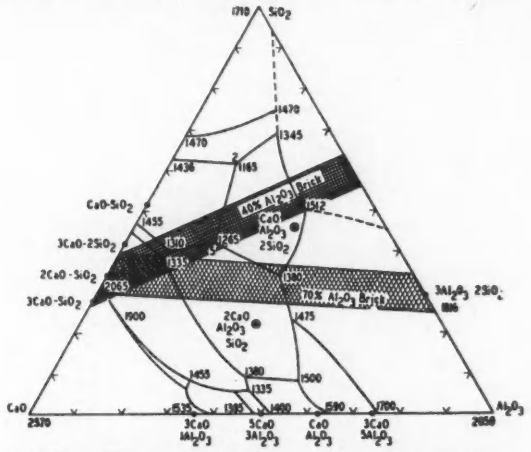

Fig. 2.—Phase-rule Diagram of the System CaO-Al_2O_3-SiO_2. The Shaded Areas Represent Mixtures of Portland Cement Clinker with Fine Clay (40% Al_2O_3) Brick and High-Alumina (70% Al_2O_3) Brick.

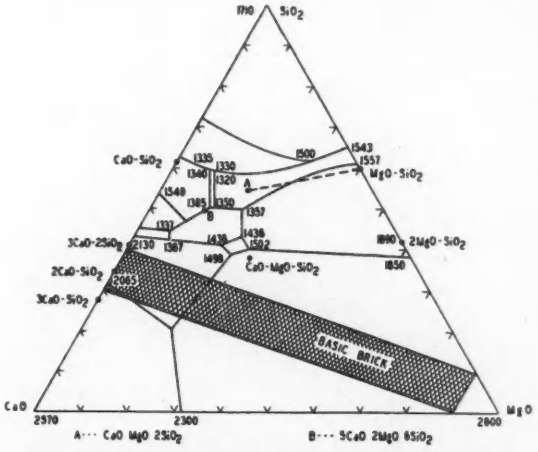

Fig. 3.—Phase-rule Diagram of the System CaO-MgO-SiO_2. The Shaded Area Represents Mixtures of Portland Cement Clinker with Magnesite Brick.

refractories manufacturer installed a high-speed hydraulic press capable of pressing at 10,000 lb. per square inch. This press increased the pressure five to ten times over that attained on the usual mechanical brick press. With the intro-

duction of high-pressure high-speed moulding it was found that compression of the air entrapped in the voids of the brick being moulded, and subsequent expansion upon sudden release of the pressure, frequently resulted in pressure cracks or laminations. This difficulty, and in order to take full advantage of the high density possible with extremely high pressure, resulted in another important development, namely, "de-airing" during pressing. This is now accomplished by the use of a vacuum, the manner of applying the vacuum differing according to whether "stiff-mud" or "dry-press" bricks are being moulded.

As some refractory mixes contain as much as 15 per cent. moisture it is necessary to control the drying operation to provide a uniform rate of moisture removal from all surfaces of the brick. Unless this is done drying shrinkage is apt to be accompanied by distortion, warping, and cracking. The benefits of controlled uniform drying have resulted in numerous improvements in drying equipment.

Burning has two important functions. One is to develop a permanent bond in the brick by partial vitrifaction of the mix, and the other is to develop temperature-stable mineral forms of the major component of the mix. Rather than delay the development of the temperature-stable form of the minerals in most refractory materials until the final firing stage, it is frequently better to start with material as nearly prestabilised as possible and reserve as the chief function of the firing treatment the maturing of the bond. This eliminates the strains (shrinkage or expansion, as the case may be) accompanying the various mineral changes involved, and the original advantage of tight interfitting of sized grains, to set up high density, is maintained. The trend to prestabilisation is well advanced. Calcined clays have always been part of the mix in making many fireclay refractories, but the temperature of calcining has frequently been lower than the temperature of firing the brick. Many of the kaolin and diaspore clay refractories intended for high heat and super-duty service now contain clays whose precalcining temperature has been increased—some to over 3,000 deg. F.

The burned magnesite used in making magnesite refractories has always been calcined to temperatures of about 2,850 deg. F. to rid the original mineral of CO_2 and to crystallise the MgO to periclase. This precalcined or burned magnesite is the base of the so-called "unburned magnesite bricks" that have come into wide use in the cement industry during the last fourteen years for extremely difficult burning zone service, and which hold out great promise of making possible satisfactory and effective insulation throughout the burning zone. "Unburned magnesite bricks" are misnamed. They acquired their name through the fact that, unlike "burned magnesite bricks," they do not require firing after pressing and drying. Having well-burned magnesite as their base they would be more properly named "chemically-bonded magnesite bricks."

An objective that both the refractories producers and cement manufacturers can well afford to pursue together is an intensive study of the conditions which shorten the life of refractories in service. Such studies would serve as a basis for studying these complex factors, so that the refractories manufacturers could endeavour to produce refractories of specific function. It is not unlikely that

such studies would also disclose ways and means whereby some consumers could, even now, improve the results they are getting with the refractories at present available.

Kilns, kiln hoods, clinker chutes, clinker coolers, dust collecting chambers, waste-heat boilers, stacks and dryers, each presents its own problem. The most severe problem, however, is encountered in the kiln itself. In order to observe the various functions of successive sections of the kiln lining, we will proceed on the premise that the essential difference between wet-process kilns and dry-process kilns is that the former, into which wet material is charged, must necessarily be longer—all other factors being equal—than a dry-process kiln into which dry material is charged. Also, that the greater length of the wet-process kiln is required thoroughly to dry the wet charge in its travel down through the kiln. The refractory requirements and service conditions encountered in

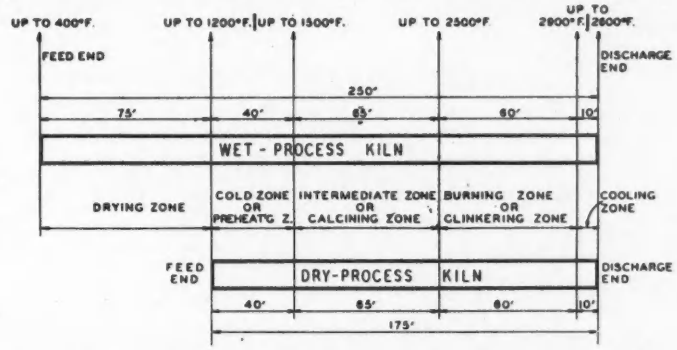

Fig. 4.—Zones Common to Wet-process and Dry-process Kilns.

the wet-process kiln from the place in the kiln where the material charged has lost all external moisture right down to the discharge end, are so similar to those in the dry-process kiln that, based on the flow of material and the reactions taking place, both kilns can be divided into four zones common to each with some overlapping of adjacent zones. These zones are indicated in *Fig.* 4. (The length of each zone for kilns of the sizes shown is approximate and will differ in different operations depending upon overall kiln operating conditions. The temperatures shown are also approximate.)

If we start at the feed end and work down to the discharge end we first encounter refractories in what we call "feed-end blocks." Their purpose is to reduce the kiln diameter to a predetermined size to bring about certain draught conditions, and also to form a dam to prevent the material from splashing or running out over the end of the kiln. Refractory feed-end blocks are frequently dispensed with in wet-process kilns, where generally the temperature at the feed end is so low that a refractory ring or dam is not called for and can be satisfactorily, and more permanently, built of steel. In dry-process kilns, however, we find refractories right to the feed end of the kiln. Except in the few cases

where the kiln shell has itself been given a sharp taper at the feed end, the ring is usually built of rather large special shapes.

Good mechanical strength and structural stability are desirable for this part of the lining. Good resistance to spalling is also desirable, although cracking or breaking of feed-end blocks is more often the result of mechanical rather than thermal causes. These features become more important as the size of the blocks increases, because the larger the block the more difficult it is to manufacture with uniform density (which, in turn, affects structural stability and resistance to spalling) and good workmanship (which, if the brick surfaces are warped,

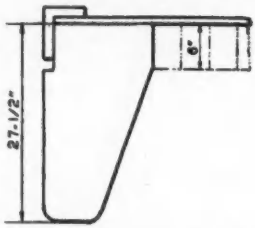

Fig. 5.—Large Feed-end Block.

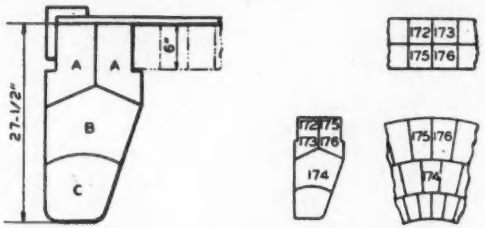

Fig. 6.—Combination of Four Smaller Blocks to Replace Block Shown in Fig. 5. The Method of Placing the Last Blocks of a Total of 176 is Shown on the Right.

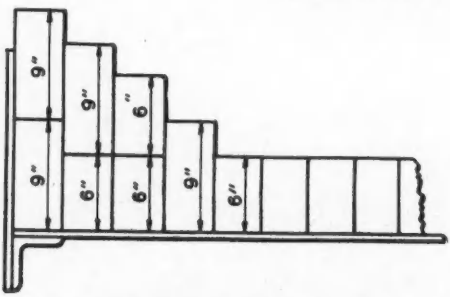

Fig. 7.—Feed-end Ring Formed of Standard 9-in. and 6-in. Blocks.

could easily result in line or point contact between adjacent bricks in the circle and so cause mechanical cracking). How one cement plant overcame a troublesome feed-end ring problem is illustrated in *Figs.* 5 and 6. *Fig.* 5 shows the design of the blocks formerly used and which cracked badly, necessitating frequent replacements. *Fig.* 6 shows the design now employed with excellent results. Here four much smaller blocks are used where formerly only one large one was used. Also, a complete ring made up of the smaller blocks represents lower first cost than a ring of the large blocks. Several cement plants are benefiting from a change from large to smaller blocks. Some have done so by simply reducing the outside chord dimension, where the block is of a shape where such change is

practical. Others are building feed-end rings using a combination of standard kiln liner shapes somewhat in the manner illustrated in *Fig. 7.*

In the drying zone of wet-process kilns the temperature is so low that refractoriness of the lining is not important. In kilns where only the wet load is in contact with the lining a good grade of fireclay brick of dense structure to resist penetration of moisture is satisfactory. However, many wet-process kilns are equipped with chain systems in the drying zone; in such cases resistance to the scouring and rubbing of the chains becomes an important factor requiring an extremely hard dense brick lining. Brick specially prepared for this service are available.

In the cold zone or pre-heating zone the temperature is low enough for any good fireclay brick to withstand, and abrasion is almost non-existent.

In the intermediate or calcining zone one frequently encounters severe refractories problems. Here the temperature range from the cooler end to the hot end is very considerable, with the hot end reaching temperatures that call for high refractoriness in the lining. In addition, the temperatures reached in this zone are so high that resistance to spalling becomes a factor of major importance, particularly in kilns subjected to intermittent service. If kilns are insulated between the refractory lining and the shell, they are invariably insulated in the intermediate or calcining zone, and this adds to the refractories problem.

Refractory service conditions are generally most severe, and lining replacements most extensive, in the burning or calcining zone. Here the temperatures may reach 2,900 deg. F. Resistance to spalling is also a very important consideration in this zone to withstand the wide and rapid temperature fluctuations during the starting up and shutting down of the kiln. Mechanical strength to withstand abrasion of clinker is also desirable. But these considerations are decidedly secondary to the ability to satisfactorily pick up and maintain a protective clinker coating. Without a clinker coating no refractory material now known will long withstand burning zone conditions in modern cement manufacturing practice. The formation of a protective clinker coating is dependent on a number of factors, including temperature, composition of the load material, composition and type of refractory used, the refractoriness of the lining material, and also, and extremely important, the effect (fusion or slagging) of the load material on the refractory at kiln temperature. These conditions vary so widely that several different types of refractories are being used successfully. In order of importance they are (1) unburned (chemically bonded) magnesite brick, (2) high-alumina brick, and (3) high-heat-duty fireclay brick. The first are a combination of burned magnesite and chrome ore held together with a chemical binder, and are the preferred burning zone lining refractory where kiln temperatures are very high and where it is either difficult or impossible to build up and satisfactorily retain protective clinker coating, even on 70 per cent. high-alumina brick. In many plants operating conditions are such that 70 per cent. alumina (Al_2O_3) brick are satisfactory and economical. A few plants can satisfactorily use 60 per cent. or 50 per cent. alumina brick, and there are a very few where a good first-quality high-heat-duty fireclay brick of about 40 per cent. alumina

can be used. With so wide a range of products being used for burning zone lining, the problem becomes one of finding the grade or classification of refractory best suited to the conditions.

The length of the cooling zone varies in different kilns, dependent on the location of the burning zone as related to the discharge end of the kiln. Factors which have a bearing on this include the kiln design (not only of the kiln itself, but also its relation to the kiln hood), the fuel used, and combustion control. Conditions are not generally severe in the cooling zone, although spalling is to be guarded against, as well as fusion of the refractory in the presence of clinker at operating temperature. The refractory should also possess good resistance to abrasion, inasmuch as a protective clinker coating is seldom built up on the lining in this zone. Developments to bring about certain desirable characteristics in the finished cement clinker, and to increase operating efficiencies, have been accompanied by a trend towards tight sealing of the kiln and kiln hood. This permits more definite combustion control, but at the same time also frequently results in higher temperatures than were formerly encountered at the discharge end of the kiln. In some instances the changes have brought about conditions so severe that the refractory problems in this zone are the same as those met with in the burning zone.

With few exceptions the last ring of bricks at the discharge end of the kiln is made up of what are called "discharge-end blocks" or "nose blocks." These are usually bricks of special design to conform to the design of the end of the kiln, which makes provision for a metal retaining ring. Bricks for this service should possess high resistance to thermal and mechanical spalling, should be resistant to abrasion by the clinker, and should be as small in size and as simple in design as is practical and permissible under fixed conditions.

(*To be continued.*)

Charts for Laboratory Calculations.

THE illustration given on page 81 is the concluding chart of the series given in the May number of this journal. The author, Mr. C. J. Knickerbocker, gives the following notes on the chart.

FLUE GAS ANALYSIS

Orsat analyses are often used in conjunction with automatic CO_2 and CO recorders. An expression of the analysis data in terms of excess air is generally desired. Time is saved by using a graphical solution method.

The computations required in the example given are:

$N_2 = 100 - (CO_2 + O_2 + CO)$, or $100 - (20 + 2 + 1)$, or $77\ O_2 - CO/2 = (2 - \frac{1}{2})$ or 1·5.

Substituting $380\ (O_2 - CO/2)N_2 - 3.8\ (O_2 - CO/2)$ gives 570/71·3 or 8 per cent. excess air.

A simple means of alignment of values on part III of the chart is by use of an 8-in. by 10-in. sheet of cellulose acetate, with $\frac{1}{4}$-in. squares, the required 90 deg. solution lines being readily selected.

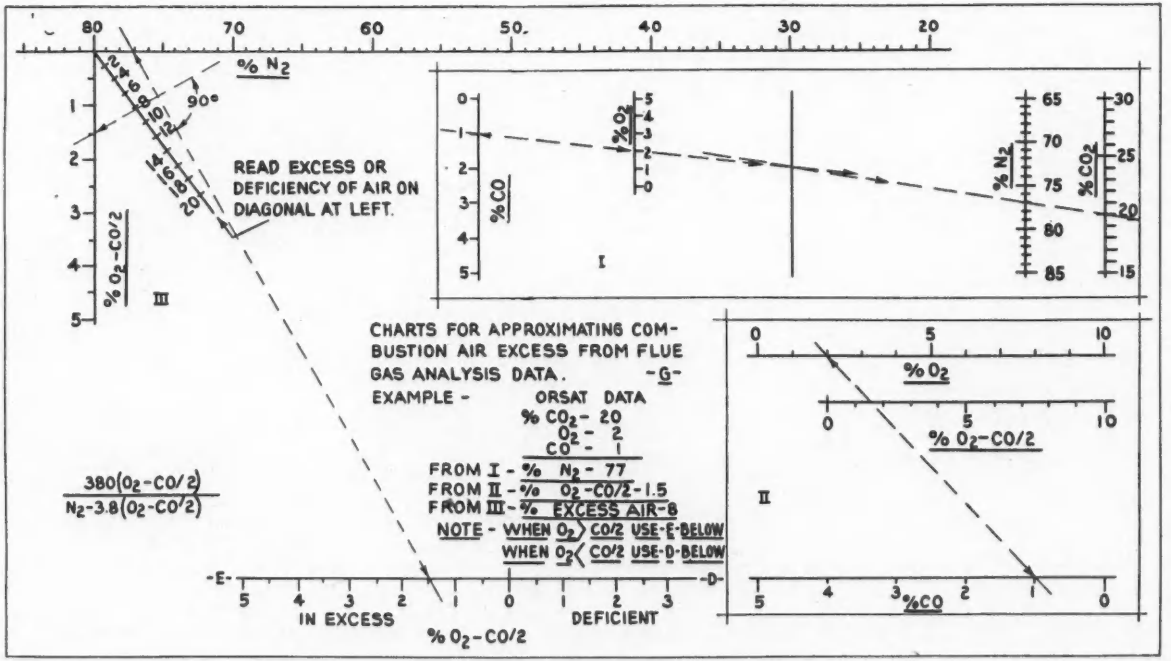

Chart for Flue-gas Analysis. (See page 80.)

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